# Big Joe Shot

On the same day, September 9, 1959, both the major preliminary flight test of Project Mercury and the final qualification flight test of the operational Atlas ICBM occurred, in separate launches from opposite sides of the United States. While NASA and STG were focusing their attention on the performance of Atlas booster No. 10-D, being launched from Cape Canaveral, most of the men behind the Atlas were watching missile No. 12-D being launched from Vandenberg Air Force Base in California. A novitiate crew of Strategic Air Command (SAC) officers and men had groomed No. 12-D for this critical test flight southwestward over the Pacific Missile Range. Likewise, neophytes from NASA stood by their payload on the Atlas 10-D, awaiting the results of its southeastward flight over the Atlantic Missile Range. If all went well this day, the Atlas would have proved itself capable both as an operational ICBM and as a launch vehicle for a Mercury ballistic flight. Reliability was something else again, but capability could be proved with one demonstration.

[200] The men from Space Technology Laboratories; from Convair/Astronautics; Rocketdyne; General Electric; Pan American, who managed the "housekeeping" of the Atlantic Missile Range; and numerous other contractors supporting the Air Force development of the Atlas, deserved to be called experts. They had had experience in launching this rocket. By contrast, NASA personnel were even greener than the SAC crew going through the countdown at Vandenberg. NASA did not intend to learn to launch its own Atlases, but STG did hope to gain some expertise for living through its launches. The job of launching Big Joe belonged to the Air Force, supported by the Convair/Astronautics team at the Cape - Byron G. McNabb, Travis L. Maloy, Thomas J. O'Malley, C. A. Johnston, and others. Charles Mathews, the STG mission director, learned much about his operational requirements working with these men on Big Joe.

Few people outside the military-industrial teams working on the Atlas could have known what was happening in the ICBM program in mid-1959.[69] The fourth and supposedly standard version of the Atlas ICBM, designated the Atlas D, rapidly supplanted the third development version, called Atlas C, during the summer of 1959. Earlier A and B models, fired in 1957 and 1958, had phased through C and into D concurrently. The Air Force had committed itself in December 1958 to supply NASA with standard Atlas Ds for all Mercury missions. The first installment on this commitment came due in September, at the same time that the weapon system was to prove itself operational. Since April 14, 1959, when the first series-D missile exploded 30 seconds after liftoff, only four other Atlas Ds had been launched, the second and third of which were partial failures or partial successes, depending upon one's point of view.[70]

In July and August, however, the two successful Atlas-D launchings were supplemented by exceptionally encouraging flights of the last two series-C Atlases. Atlas 8-C had flown on July 21, bearing "RVX-2," or the first ablative reentry nose cone adapted to the Atlas. It was especially welcome to STG officials; both the flight and the recovery provided demonstrative evidence to reinforce STG's commitment to the ablation principle for the Mercury heatshield.[71]

Joe is a common name, but there was nothing common about the big Atlas missile and the Mercury payload that stood poised upright at launch complex 14 at Cape Canaveral on September 9, 1959. Some had hoped that Big Joe would skyrocket on July 4, but the launch date was postponed until mid-August by the Air Force because the booster did not check out perfectly at first. Then it was put off until early September by STG engineers, who were stymied by troubles in the sophisticated instrumentation and telemetry. Finally, on the evening of September 8, Atlas 10-D, the sixth of this model to be flight tested, stood on its launch pad at Cape Canaveral with a replica of the Mercury capsule (minus an escape tower) at its tip. All NASA waited for the countdown to begin at midnight. About a fourth of the Space Task Group members were at the Cape for the "Atlas ablation test." From this first full-scale, full-throttle simulation of the reentry problem, every member could expect further task definitions.

[201] If Atlas 10-D should fail, if the boilerplate capsule should fail its test or be lost, then a backup shot, Big Joe II, would have to be made. But without proof that the ablation heatshield could actually protect a man from the intense frictional heat of reentry, and without dynamic evidence that the frustum-shaped spacecraft would actually align itself blunt-end-forward as it pierced the atmosphere, all the rest of the "R and D" invested in Faget's plan would avail little.[72]

The nose-cone-capsule for Big Joe, handcrafted by NASA machinists, had no retrorocket package. The inner structure held only a half-size instrumented pressure vessel instead of a pressurized cabin contoured to the outer configuration. Built in two segments, the lower half by Lewis and the upper by Langley craftsmen, the main body of the spacecraft replica was fabricated of such relatively thin sheets of corrugated Inconel alloy in monocoque construction that the appellation "boilerplate" capsule was especially ironic.[73]

For this model of the Mercury payload, more than a hundred thermocouples were installed around the capsule skin to register temperatures inside and under the heatshield, sides, and afterbody. Jacob Moser and a group of instrumentation specialists from Lewis had developed a multiplex system for transmitting data over a single telemetry link from all thermocouples plus 50 other instruments, including microphones, pressure gauges, and accelerometers.

Back in Cleveland, three controls engineers, Harold Gold, Robert R. Miller, and H. Warren Plohr, had designed a "cold-gas" attitude control system, using high-pressure nitrogen for fuel. They had worked directly with Minneapolis-Honeywell to devise the gyros, logic, and thrusters for the critical about-face maneuver after separation. It was essentially unique in its use of cold-gas nitrogen thrusters rather than the "hot-gas" hydrogen peroxide systems that Bell Aerosystems had developed for the X-15 program.[74]

To STG novices watching the launch preparations, the Atlas and the organization of people it required to get off the ground seemed incredibly complex. But they themselves were not well organized even for their sole responsibility with the payload. Big Joe had three bosses, all at work under Mathews. Aleck C. Bond, the Langley heat-transfer specialist, had accepted from Faget almost a year ago the responsibility for the overall mission success. B. Porter Brown, the Langley engineer first sent to pave the way for STG at the Cape, acted as STG's chief liaison with the Air Force-Convair team. And Scott H. Simpkinson, leading the group of about 45 test-operations people from Lewis, had been living with the capsule for Big Joe in a corner of Hangar S since the second week in June, when checkout and preflight operations tests began. The NASA-Goddard crew still held most of the hangar space in preparation for *Vanguard III*, their culminating launch, scheduled later in September.[75]

Porter Brown bore the title of NASA Atlas-Mercury Test Coordinator and worked - along with NASA Headquarters representative Melvin Gough - under nominal direction from the Missile Test Center. To fathom the complexity of launch operations and organizations at the Cape required expertise, tact, and drive. [202] Security restrictions were so strict for the Atlas, and agencies and launch crews so compartmentalized, that horizontal or interpersonal communications in the lower echelons were virtually nonexistent. Brown had to keep vertical communications open and establish STG's "need-to-know" at every step.[76]

To launch a missile required a stack of documents almost as tall as a gantry. Documents called "preliminary requirements," "operations requirements," "operations directives," "test directives," and innumerable other coordinating catalogs had to be circulated and their orders followed before, during, and after getting a rocket off the ground. To active young engineers with a mission, this paperwork could only be frustrating, but Air Force experience had shown the value of the documentation system in imposing order on a chaotic situation.[77]

Atlas 10-D was programmed to rise, pitch over horizontally to the Atlantic before it reached its 100-mile peak altitude, then pitch down slightly before releasing its corrugated nose cone at a shallow angle barely below the horizontal. [203] In the near vacuum of space at that altitude, tiny automatic thrusters in the capsule should make it turn around for a shallow reentry into the stratosphere. The friction of the air, gradually braking the speed of the descent, would dissipate the kinetic energy imparted to the capsule by the Atlas. An incandescent cauldron of this transformed energy would envelop the capsule like a crucible as it penetrated denser air. It was hoped that enough of this heat would be deflected by the slip stream and boiled away into the turbulent boundary layer of the shock-wave to protect the capsule from vaporization. This flight should simulate closely what a man must ride through if he was to live to talk about an Atlas-boosted, Mercury-returned orbital flight around Earth.

About 2:30 a.m., a 19-minute hold in the countdown was called to investigate a peculiar indication from the Burroughs computer that was to guide the launch. A malfunction was found in the Azusa impact prediction beacon, a transponder in the booster. Since there were several redundant means, including an IBM machine that was part of the range safety system, for predicting the impact point, the trouble was ignored, the countdown resumed, and liftoff occurred at 3:19 a.m.[78]

It was a beautiful launch. The night sky lit up and the beach trembled with the roar of the Rocketdyne engines. For the first two minutes everyone was elated. Then suddenly oscillograph traces indicated that the two outboard booster engines had not separated from the centerline sustainer engine, as they were supposed to do when their fuel was exhausted. Flight controllers and test conductors in the blockhouse and control center began to worry about "BECO" (or booster engine cutoff) as contradictory signals appeared on their panels and computer readout rolls. Apparently all systems within the capsule were performing as planned, but the capsule seemed not to do its half-somersault. The added weight of the booster engines retarded velocity by 3,000 feet per second. The Burroughs computer predicted an impact point about 500 miles short. All eight reaction control jets seemed to be working perfectly, yet the reentry attitude could not be verified before the telemetry blackout occurred as the capsule skidded back into the atmosphere.[79] No one could ascertain what had happened during that 20-minute flight unless the recovery forces downrange could retrieve the capsule and its onboard tape recordings.

Six ships of Destroyer Flotilla Four began racing uprange at flank speed. Patrol and tracking planes started flying their search patterns. Before dawn, tracking ships and downrange tracking stations detected the sofar bomb explosion underwater, and provided new coordinates for the point of impact. As the sun rose over the sea, a Navy P2V Neptune patrol plane, homing in on a sarah beacon signal, reported sighting the capsule bobbing in the water. It vectored the nearest destroyer, now still over 100 miles away, to the green-dyed area for retrieval. It was still too early to tell whether the primary objectives of Big Joe had been achieved. But as the morning progressed, more evidence from the range made it appear that all telemetry had functioned properly. If the capsule could be [204] recovered before it sank, the most important objective, finding out how well the capsule's ablation shield had endured reentry, could be evaluated quickly.

While eager newsmen at the Cape were being cautioned to avoid erroneously identifying this custom-built prototype as the Mercury capsule, technicians were busily analyzing "quick-look" data that would give more information about booster and payload separation performance, the attitude control system, the internal and external temperature history of the model, noise and vibration levels, telemetry and tracking effectiveness, and acceleration and deceleration peaks.

About seven hours after launch, exultation swept over the Big Joe launch team at the Cape when the destroyer *Strong* reported that she had netted the precious capsule intact and secured it on deck. The terrestrial return trip by water and air required another 12 hours. As soon as the transferring cargo plane arrived at Patrick Air Force Base, the capsule was loaded onto a dolly, and a police escort cleared the way for the shrouded trailer bearing the tangible remains of the Big Joe mission along the 15 miles through Cocoa Beach to Cape Canaveral.

When the capsule arrived back home in Hangar S, about midnight, every NASA person at the launch site that day gathered around the capsule for a joyous autopsy. Gilruth, Faget, Mathews, Bond, Brown, and Simpkinson stood by as someone dropped the canvas veiling the secret heatshield. The group marveled at the superb condition of their archetype. Bond ran his fingers over the now cool glass beads on the face of the ablation shield, noticed that the afterbody was barely singed. Brown scratched the white-paint legend "United States" and found it hardly discolored. Although one of the afterbody recovery eyes was welded shut by reentry heating, a piece of masking tape, which Simpkinson had allowed to remain, was still intact inside the outer conical shell. A tired but happy crew unscrewed the two halves of the inner pressure vessel and handed to Gilruth a letter that had been sealed inside and signed by 53 people under Mathews in anticipation of this occasion:

> This note comes to you after being transported into space during the successful flight of the "Big Joe" capsule, the first full-scale flight operation associated with Project Mercury. The people who have worked on this project hereby send you greetings and congratulations.[80]

Within a week, data reduction made possible the reconstruction of the inflight history of Big Joe. As suspected, the outboard engines had failed to stage after booster engine cutoff, and the additional weight degraded the Atlas velocity about 3,000 feet per second. This meant the trajectory of the flight path had been steeper and slightly lower than planned and that the sustainer engine had powered the capsule into a steeper downward course before burnout. Without a positive force to divide the two objects in free fall, the capsule had separated from the booster about 138 seconds late, after all of its high-pressure nitrogen fuel was expended in trying futilely to turn both booster and spacecraft around for reentry. When it finally broke loose from the launch vehicle at an altitude [205] of 345,000 feet and at a space-fixed speed of almost 15,000 miles per hour, the capsule was an exhausted, passive, free-falling body. Yet by virtue of its configuration and center of gravity, the capsule turned itself around without the aid of either thrusters or damping controls and reentered the atmosphere successfully. The dynamic stability of the capsule configuration was so good that doubt of its ability to damp out its entry oscillations was also ended.

The heat pulse sustained in the actual Big Joe trajectory was shorter but considerably more severe than planned. If STG had been testing a beryllium heat sink shield, these untoward conditions would not have proved anything. For the ablation heatshield, the length of the heat pulse was sufficient to prove the value of the approach. The sequencing, structures, instrumentation, and cooling system had all worked well. The recovery of the capsule inspired so much confidence among STG leaders that Big Joe II, the backup launch, was canceled within three weeks.

[206] Cores and slices taken from the conservatively designed heatshield at many locations proved that the heating was uniform over its face and that its structural integrity had survived impact without compromise. The depth of ablation charring was shallow enough to leave at least two-thirds of the fiber-glass material in pristine condition. Bond and Andre J. Meyer were especially pleased with the large margin for error represented by the thickness of the heatshield remaining. Subsequently, they were able to reduce the thickness and the weight of the shield by almost one half.

One note of caution remained in all the jubilation following Big Joe. Leonard Rabb, the head of Faget's theoretical heat transfer section, signed a memo on October 7 demanding action to prove that the short heat pulse on Big Joe could be disregarded. "Calculations indicate," said Rabb, "that the present Mercury heatshield will *not* survive a reentry due to natural decay." If retrorockets should be lost or become inoperative and if the ablation shield in orbit should have to sustain and dissipate the long, slow building of the heat pulse over 24 hours or so, catastrophe would result, Rabb warned:

> Under no circumstances should the weight of the heat shield itself be shaved. Recent calculations cast doubt on the shield's performance, not only for natural decay reentry but for the one retro [rocket instead of three or two] case as well.[81]

By the end of October, the working papers giving the results of Big Joe were published, and gradually the lessons learned from this shot were incorporated in a number of major redesign decisions. The features that became standard for Project Mercury as a result of Big Joe have been summarized by Aleck Bond:

1. In view of the excellent performance of the ablation shield, the back-up beryllium heat sink shield was dropped from further consideration for Mercury orbital missions.
2. The basic heat shield fabrication techniques employed for the Big Joe shield were adopted for the Mercury heat shield.
3. The detailed temperature measurements made on the Big Joe shield provided for an efficient design thickness for the Mercury shield.
4. The afterbody heat transfer measurements indicated a need for heavier external thermal protection than had been provided for the Mercury spacecraft, and as a result the shingles on the conical afterbody were thickened and on the cylindrical afterbody the original René shingles were replaced with the thick beryllium shingles in order to handle the high heating loads in this region.

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> The ability of the spacecraft to survive the severe test of reentry from near-orbital velocities in spite of its unprecedented release conditions, is certainly worthy of note. The heat shield performance was excellent and the results indicated that the original design concepts were sound. The spacecraft performance as a freebody reentry vehicle was exceptional. An important characteristic of the Mercury design was demonstrated; that the spacecraft could [208] reenter the atmosphere at high angles of attack and maintain the heat shield forward attitude without the aid of a control system![82]

The elation of the Task Group over the dynamic proof of its passive design of Mercury was not shared by the Atlas people. Their booster 10-D, having failed to stage, performed only marginally and in fact was classed a failure by the Air Force and STL. But across the country, on the Pacific Coast, Atlas 12-D, launched by the SAC crew under the tutelage of Convair/Astronautics and STL, performed as a true ICBM on a 5,200-mile flight to its target in the South Pacific. Immediately thereafter the Air Force announced the Atlas was now operational. Apparently the force-in-being totaled only the two missiles erected in training gantries at Vandenberg, but the delicate balance of power could not wait for the buildup of numbers.[83]

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69 When they become available, see the following classified historical monographs written by Air Force historians: Lee Bowen, *The Threshold of Space: The Air Force National Space Program, 1945-1959*, Sept. 1960; Max Rosenberg, *The Air Force in Space 1959-60*, June 1962; Clarence J. Geiger, *History of the X-20A: Dyna-Soar*, Air Force Systems Command Hist. Pub. Series, 63-50-I, Oct. 1963; Robert L. Perry, *Origins of the USAF Space Program, 1945-1956*, Air Force Systems Command Hist. Pub. Series, 62-24-10, 1961; Ethel M. DeHaven, *Aerospace - The Evolution of USAF Weapons Acquisition Policy, 1945-1961*, Aug. 1962; *Comparisons of NASA Manned Space Program and USAF Manned Military Space Proposal*, Feb. 25, 1960.

70 George Alexander, "Atlas Accuracy Improves as Test Program Is Completed," *Aviation Week*, LXXVIII (Feb. 25, 1963), 69-75.

71 Mark Morton, "Progress in Reentry-Recovery Vehicle Development," pamphlet, Missile and Space Vehicle Dept., General Electric Co., Philadelphia, Jan. 2, 1961, 14.

72 Kehlet and Bruce G. Jackson, STG aerodynamicists responsible for the aerodynamic stability of the Big Joe capsule on entry, wanted this to be a free flight (with the ACS nonoperative from turnaround to max q), but shortly before the launch day "somebody blew the whistle" and changed the plan to full operation of the ACS throughout the flight. As it turned out, Kehlet and Jackson got their wish after all: interviews, Downey, Calif., Aug. 27, 1964, and Houston, Sept. 13, 1965.

73 "Project Mercury Status Report No. 4," 1, 15-18, 36. Cf. "Project Mercury Status Report No. 3," Ms., Bond, for Project Mercury Tech. Hist. Program, "Big Joe," June 27, 1963. According to Jack A. Kinzler, Langley shop foreman, the Big Joe capsule culminated an intensive manufacturing development that fed directly into STG's relations with McDonnell; see Kinzler draft Ms., "Manufacturing by NASA for Project Mercury," for Mercury Technical History, Aug. 30, 1963.

74 Memo, Bond to Project Dir., "Visit to Lewis Laboratory with Regard to Instrumentation and Construction of Big Joe Capsule," April 28, 1959. Cf. Ms., Norman Farmer et al., "Instrumentation," for Project Mercury Tech. Hist. Program, June 27, 1963, 12. Ms., Harold Gold, "Attitude Control System for Project HS-24," June 9, 1959; Warren Plohr, interview, Cleveland, May 1, 1964.

75 Bond, interview, Houston, March 13, 1964; B. Porter Brown, interview, Cape Kennedy, April 30, 1964; Scott H. Simpkinson, interview, Houston, June 2, 1964. See also memo [Simpkinson], NASA-(MTQD) to all concerned, "Personnel Assignments for First Mercury FRF and Launch," Aug. 31, 1959.

76 The industrial society at the Cape is well described by Richard A. Smith, "Industry's Trial by Fire at Canaveral," in Editors of *Fortune, The Space Industry: America's Newest Giant* (Englewood Cliffs, N.J., 1962), 65 et seq.

77 For the first STG countdown procedures, see four-page ditto, "HS-24 Countdown of Major Events," in Simpkinson's papers; STG. "Test No. HS-24 General Information for Recovery Forces," NASA

Project Mercury working paper No. 101, Aug. 14, 1959.

78 The following description of the Big Joe flight is based on the documents cited below and on Simpkinson's eyewitness account and vivid recall in interview; "Preliminary Flight Test Results of Big Joe," NASA Project Mercury working paper No. 107, Oct. 12, 1959; "Qualification Tests on the Big Joe Recovery System," NASA Project Mercury working paper No. 108, Oct. 27, 1959. Cf. memo, Warren J. North to T. E. Jenkins, "Flight Mission Data for Project Mercury," Jan. 14, 1960, and John P. Mayer, comments, Sept. 8, 1965.

79 Memo, Low to Administrator, "Big Joe Shot," Sept. 9, 1959. Carl R. Huss, in comments, Oct. 5, 1965, called attention to the fact that "the reliability of Atlas staging was about as high as it could be" until Big Joe.

80 Letter, "Big Joe team" to Gilruth, Sept. 6, 1959. This artifact is one of Gilruth's mementos, now sealed in plastic and framed in a plaque on the wall of the office of the director, Manned Spacecraft Center. See also Huss comments.

81 Memo, Leonard Rabb to Chief, Flight Systems Div., "Heat Shield Performance," Oct. 7, 1959. Bond, interview, Houston, Sept. 22, 1965 . See also "Results of Studies Made to Determine Required Retrorocket Capability," NASA Project Mercury working paper No. 102, Sept. 22, 1959. In addition, Alan B. Kehlet directed Dennis F.Hasson to investigate an inflatable sphere to accomplish the decrease in decay time for a retrofire failure and to stabilize the capsule in the event of a control system failure. This study was published as NASA Project Mercury working paper No. 113, "Preliminary Study Using Inflatable Spheres for Aerodynamic Stabilization During Reentry," Nov. 18, 1959.

82 Bond, "Big Joe," 23, 24, 25. The last paragraph of this quotation is somewhat anachronistic in that it disregards the last-minute debates among aerodynamicists over the dynamic stability issue: see ante footnote 72. Regarding afterbody heat protection, other evidence from wind tunnels and from the Navy's Ordnance Aerophysics Laboratory at Daingerfield, Texas, was accumulating also, pointing toward the need for beryllium or a like material to act as heat sink shingles around the antenna canister.

83 Alexander, "Atlas Accuracy Improves."

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